

User Operational Evaluation System of Unmanned Underwater Vehicles for Very Shallow Water Mine Countermeasures

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Abstract - The United States Navy's Explosive Ordnance Disposal Program Office within the Program Executive Office, Littoral and Mine Warfare, utilized a User Operational Evaluation System (UOES) as an essential element in its procurement strategy for Unmanned Underwater Vehicles (UUV) for Very Shallow Water (VSW) Mine Countermeasures (MCM) Operations. From April 2001 through April 2003 six members of the Naval Special Clearance Team ONE routinely operated and evaluated two Woods Hole Oceanographic Institution (WHOI) constructed REMUS UUVs. Included were numerous military exercises and scheduled equipment tests in different operational environments around the world. The UOES phase provided invaluable performance data and "war fighter" feedback on vehicle configuration, unit requirements, integration concerns with existing systems, and operational employment of a small UUV in the VSW MCM area of operations (littoral waters with depths of 3-12 meters). A performance specification was developed based largely on information received during this phase, and a competitive procurement strategy is underway to field a more robust capability by FY 2005.

I. INTRODUCTION

Naval Special Clearance Team ONE (NSCT-1) is a highly specialized military unit whose function is the clearance of mines and obstacles in littoral waters prior to an amphibious assault against an enemy shore. One of the Detachments within this unit, the Very Shallow Water Mine Countermeasures (VSW MCM) Detachment, is assigned clearance of anti-invasion mines and obstacles in water in depth of 3-12 meters. The VSW MCM Detachment was established in 1996 as a result of the Navy's inability to breach the underwater minefields in waters off Kuwait during the Persian Gulf War in 1991. The VSW MCM Detachment became a department of NSCT-1 once NSCT-1 was commissioned in the fall of 2002.

The VSW MCM Detachment currently uses Marine Mammal Systems and specially trained and equipped divers to locate and clear the VSW zone of mines. The

intention has always been to remove divers and Marine Mammals from this extremely hazardous undertaking and replace them with Unmanned Underwater Vehicles (UUVs) that can perform this function. Within the Navy's Program Executive Office for Littoral and Mine Warfare, the Program Office for Explosive Ordnance Disposal (EOD) determined that current UUV technology had matured to the point that this transition could begin to occur using a User Operational Evaluation System (UOES).

The UOES is a Department of Defense acquisition strategy which puts new military systems into the hands of the war fighter early in the often lengthy acquisition cycle. The intention is to let the end user evaluate the equipment by using it as they would in a military operational environment. The approach allows technology that may not have fully matured, to be evaluated in such a way that user feedback is put into the iterative process of developing operational requirements that drive the Request for Proposal for the final production equipment.

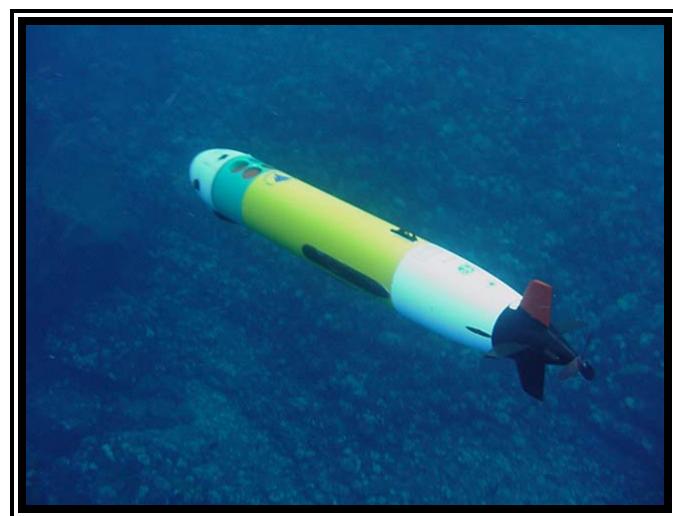


Fig. 1. REMUS searching water off of Kaho'olawe, Hawaii.

The UUV procurement process for VSW began in early FY 2000 with a multi-pronged approach to acquiring hardware that would allow the operator to

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search the VSW zone for anti-invasion mines. An Analysis of Alternatives (AoA) study was commissioned to examine the state of technology of small UUVs at present and in the near future. The AoA incorporates operational user needs, documents limitations of existing systems, and technological applications, and addresses program cost and risk from a lifecycle perspective [1]. The AoA panel was made up of Navy VSW clearance divers, civil service engineers, and contractor procurement and logistic specialists that examined the small UUV program from every possible perspective. An industry survey was conducted using a "Sources Sought" announcement in the Commerce Business Daily. An extensive analysis period followed the receipt of the letters of interest from several civilian vendors and research centers.

Running parallel to the AoA was a Requirements Working Group (RWG) tasked with generating, prioritizing, and validating operational requirements that must be met by any small UUV procured in the future for VSW MCM purposes. The RWG met regularly to ensure that all the requirements of the EOD Staff and operational personnel were adequately addressed. Again, the RWG was made up of mostly military operators, officers familiar with the VSW MCM mission, and various other subject matter experts on UUVs and MCM operations.

One of the early recommendations from the AoA study team was to institute a UOES for the Search, Classify, and Map (S-C-M) UUV program similar to programs used by several military missile programs in the past. The objective of the UOES is to get the technology into the hands of the end user as soon as possible in the acquisition cycle to validate the utility of the system, and to finalize the requirements and specifications for the production system. The UOES was especially useful in the case of the UUV program to gauge if the current state of the technology was too complex for its intended user or too delicate for its intended military operational environment. An abbreviated procurement process was initiated to purchase limited numbers of two types of vehicles possessing different approaches to the VSW MCM problem.

Unfortunately, one of the companies withdrew from consideration due to internal contract difficulties. The remaining prototype was the Remote Environmental Monitoring UnitS (REMUS) developed at Woods Hole Oceanographic Institution (WHOI) by the engineering group at the Oceanographic System Laboratory led by Christopher von Alt. The REMUS was developed using Office of Naval Research and Special Operations Command funding.

The REMUS is a small (158 cm x 19 cm), lightweight (36 kg), relatively inexpensive (\$250K) UUV designed to survey the ocean floor and water column, collecting bathymetry, salinity, temperature, current, and high frequency side scan images of the bottom. The

REMUS is preprogrammed prior to operation and is launched from a small rubber boat by two personnel. The vehicle navigates using a Long Baseline Navigation system that interrogates two transducers anchored at predetermined positions and triangulates its position which is time stamped to the side scan sonar images and oceanographic data [2].

Two REMUS vehicles were purchased for the UOES, identical except for different side scan frequencies. One of the objectives of the UOES was to compare two different sonar frequencies and determine which one provided the greatest utility for the VSW MCM mission. The tradeoff with the side scan sonar technology is that the higher the frequency, the higher the resolution; however, the shorter the search range. With the size of the mines that are typically found in the VSW region (less than a meter in length), resolution was critical to mission success; however, search swath and thus search time had to be within certain tactical time constraints to complete a VSW MCM mission near an enemy shore.

Prior to delivery of the vehicles to the Navy, a comprehensive Memorandum of Agreement (MOA) was written and signed by all of the involved parties [3]. The Navy's belief in the concept of UUVs as a future force multiplier was evident by its commitment of six VSW members to the project for two years, considering that the personnel had to be drawn from other operational units without replacement [4].

The MOA provided a means to designate the roles and responsibilities of the different units involved, specifically which unit was responsible for funding different aspects of the project, and who was responsible for writing and approving reports. The EOD Program Office hired a contractor specifically to act as an on scene agent for the Program Office during the UOES, recording data, interfacing with military operators, and acting as a liaison between the VSW and the UUV vendor for vehicle repair. A goal of at least 12 days of UUV operation per month was agreed upon by all parties to ensure an adequate amount of data was gathered to support the objectives of the UOES.

A UOES evaluation plan [5] was also created to outline the specific execution of the day-to-day use of the UUVs. The plan consisted of seven different phases during the initial 18-month UOES period. The phases are listed in Table 1.

TABLE 1
LIST OF UOES PHASES

Phase	Description
A	Vendor Supplied Training, Basic Operations
B	Baseline Tactics
C	Concept of Operations Variations
D	Integration Operations
E	Environmental Variations
F	Blind Tests
G	Fleet Exercises

A maintenance contract was also entered into between the EOD Program Office and WHOI, specifying not to exceed amounts of annual maintenance and procedures for shipping vehicles for repair. The maintenance concept proposed by WHOI was to have a sealed vehicle that would need minimal operator level maintenance. If a vehicle did experience a component failure, it would be checked by the operator, with phone assistance from WHOI, using the Graphical User Interface on the accompanying lap top computer. Once it was determined that a hardware problem existed, the vehicle was shipped by express commercial courier back to WHOI for repair. WHOI designed the vehicles and shipping container to be less than 68 kg, and within the size limitations of commercial express shippers.

Progress reports were generated monthly for the first three months, then quarterly afterwards in order to capture and document the lessons learned during the UOES. A performance tracking Microsoft Access Database was created to record mission data; another database was created to track equipment failures and parts ordering. The support contractor hired by the EOD Program Office drafted the reports based on the military operators' input and maintained the database to minimize the administrative burden placed on the military operators. The military chain of command reviewed and approved all correspondence prior to its release to the EOD Program Office.

The following listed UOES phases were not always sequential; some testing was done as the test locations became available, and some phases were combined due to scheduling requirements.

II. PHASE A – VENDOR SUPPLIED TRAINING, BASIC OPERATIONS

Once the UOES personnel were identified, and the two vehicles were procured and delivered to the Naval Amphibious Base in Coronado, the first phase of the UOES commenced. The first phase of the UOES, Phase A, consisted of vendor-supplied initial training and a period of equipment familiarization.

Four instructors from WHOI provided classroom and practical training for five members of the VSW MCM Detachment (now a part of the NSCT-1). The REMUS Operations course was conducted at the VSW MCM Detachment at the Naval Amphibious Base in Coronado, California from 04 - 14 June 2001. The REMUS Operations Course consisted of classroom lectures followed by hands-on instruction with a daily open-ocean training mission on the REMUS vehicle. The three main sections of the training were Basic REMUS Operations, PARADIGM (Portable Acoustic/Radio Geo referenced Monitoring) Tracking Buoy Operations, and Sonar Interpretation Training. Specific areas of training were as follows:

- Perform pre-mission planning and programming
- Conduct vehicle deployment and recovery
- Operate and track vehicle in an abbreviated mission scenario
- Operate the vehicle with the PARADIGM radio tracking buoys
- Locate and recover a disabled vehicle
- Perform post-mission downloading and processing
- Perform basic vehicle maintenance
- Side scan sonar theory, interpretation, and software tools for measuring and marking contacts

During the second week of training, a circuit board failure on one of the vehicles necessitated sending one of the vehicles back to WHOI for repair. Problems with a battery cell charging circuit and the Acoustic Doppler Current Profiler also plagued the vehicles early in the program. Official Government acceptance of the vehicles was delayed until the problems were resolved.

Once the course was complete, the UUV Platoon started to operate the vehicles without assistance from the vendor. Simple missions were set up off the Coronado Silver Strand training areas, from the surf zone to several hundred yards offshore. Inert target mines shapes were placed in the VSW zone to allow the operators to locate and classify mine-like contacts using the files downloaded from the REMUS UUV. The operators gained confidence and proficiency launching and recovering the vehicles in the open-ocean environment. A typical workweek involved three days of UUV operations in the open-ocean training area, followed by a day of post-mission processing and maintenance, and a day of mission planning and administrative upkeep. Mission data were entered in the appropriate database weekly, and the lessons learned summary was drafted at the end of the phase.

III. PHASE B – BASELINE TACTICS

Once the operators became competent in running missions, the concentration shifted to establishing and documenting the details of using the UUV as an operational MCM tool.

One of the areas that Phase B concentrated on was comparing the performance of the two different frequency side scan sonar installed on the vehicles. One frequency gave longer range but sacrificed resolution, while the other was limited in its range but had high resolution.

Another area of emphasis was in deciding the optimum search geometry for conducting S-C-M MCM missions under different environmental and tactical conditions with the UUV. Standard Operating Procedures (SOPs) were created based on the results of these missions. Load lists and contingency

procedures such as lost vehicle and mission abort were developed and incorporated into the SOPs.

Data continued to be collected and analyzed on the performance of the UUVs under varying environmental conditions. The data were used to validate, and in some cases create, the specifications that were used during the competitive bidding process for the production S-C-M UUVs. Manpower, training effectiveness, and maintenance requirements were also analyzed and tracked. The REMUS required minimal user maintenance. Rinsing and battery charging were the extent of the routine maintenance. Unscheduled operator maintenance was limited to fin and propeller changes.

During this period, the UUV Platoon was tasked with two real-world operations. The first was to survey several sites around Kaho'olawe, located in the Hawaiian Islands near Maui. Kaho'olawe had been used for naval target practice since World War II, and the U.S. Navy was conducting ordnance remediation on the island prior to returning it to the State of Hawaii. The UUV Platoon successfully conducted underwater surveys of several proposed boat mooring sites around the island, and gained valuable operational knowledge concerning side scan interpretation in heavy coral growth bottoms. Fig. 1 shows the REMUS operating off of Kaho'olawe. This flyaway operation to a remote site also allowed the UUV Platoon to validate their SOPs and load lists.

The second real-world tasking was a search of the Aircraft Carrier Basin in San Diego, California following the terrorist attacks of 11 September 2001. Two Aircraft carriers were scheduled to dock at the piers, but it was uncertain if it was safe to do so given the security threat that the country was experiencing at the time. In one night, the UUV Platoon was able to survey the entire Carrier Basin, providing contacts that were examined by divers the next day.

IV. PHASE C – CONCEPT OF OPERATIONS VARIATIONS

During Phase C, missions were developed to push the performance envelope of the vehicles, and develop new ways of employing the vehicles under varying environmental and tactical conditions.

Long transits off-shore and along the shore were made using Ultra Short Baseline navigation that the vehicles used to home in on transducers. The tactics were designed to allow the human operators to stay as far from a hostile shore as possible, while still maintaining control over the vehicles during the mission.

Long duration missions were also designed to test the reliability of the vehicles, as well as to gather data on the mean time between operational failures. Significant maintenance findings during this period were the breakdown of potting material in the motor armature

and in the navigation transducer. The vehicle manufacturer switched to a different type of potting material to counteract the effect of salt water on crucial components. Without the benefit of the UOES vehicle operating hours, these findings would not have been discovered until well into the production cycle causing delays and cost increases.

During this period, an underwater survey was conducted offshore of Camp Pendleton to locate a suitable ocean bottom type for testing another UUV system. Due to the large area to be surveyed, the PARADIGM radio tracking buoy system was used to track and control the UUV during eight hours of side scan survey a day. A repeater was used to allow the command post to be situated five miles from the operations area. After the vehicle was launched by a small boat, the crew returned to a standby position at a small boat harbor within 15 minutes of the operations area. The command post monitored the position and status of the UUV while remaining in radio communications with the recovery boat in the harbor. This allowed the crew to be sheltered from the elements during the survey while still maintaining control over the vehicle. The PARADIGM system also allows the command post to send an abort signal to the vehicle to return it to the recovery point if conditions dictate.

An exercise that incorporated all aspects of the Very VSW MCM Detachment took place in November 2001. For the first time, the UUV Platoon was integrated with the Marine Mammal System Platoon and the Dive Platoon. This was also used as an opportunity to conduct a "blind test" of the UUV Platoon using test personnel from the EOD Technical Center in Indian Head, Maryland.

V. PHASE D – INTEGRATION OPERATIONS

Phase D evaluated an important consideration for any UUV, namely compatibility with existing Navy Mine Warfare and NSCT-1/VSW systems. Information passed to and from the UUVs had to be compatible with the Navy's Mine Warfare Environmental Decision Aid Library (MEDAL) system. As described in section IV, an exercise integrating the three elements of the VSW MCM Detachment was held off the coast of Camp Pendleton, California in November 2001. Important lessons learned were generated concerning how the three Platoons exchanged contact information. Problems were discovered processing large MEDAL messages from REMUS generated mine-like contacts. The problems were addressed with the vendor and quickly corrected.

Besides the reporting compatibility issues, a need was identified early on in the project to make the navigation hardware work with both the UUV and the diver navigation system. The goal was to reduce the navigational error for the divers reacquiring contacts provided by a UUV mission. Unfortunately, the first

attempt at modifying the vehicle and navigational transponders for diver navigation compatibility did not work and required additional work before becoming operationally available. Again, the operator feedback concerning what was required operationally and what actually worked in the field, versus what worked on the bench in the laboratory was crucial to making the program a success.

Another advantage of using the vehicles during operations with other elements of the unit was that it exposed the leadership to the technological capabilities of the equipment. Several senior members of the unit initially had reservations about the capabilities and maintainability of the UUV. Once the leadership observed the UUV in operation, and sampled the environmental and mine intelligence data it provided, they quickly bought into the utility of the small UUV as an effective VSW mine-hunting tool.

VI. PHASE E – ENVIRONMENTAL VARIATIONS

An important part of the evaluation was to ensure that the equipment functioned under all likely environmental conditions. Testing locations were selected based on similarities to anticipated deployment sites. Variations in bottom type, salinity, water temperature, current, and magnetic variation were taken into consideration when selecting testing locations. Data recorded during deployments to different areas during various military exercises were used to enhance the existing dataset.

The first location selected for environmental testing was Crescent Harbor off Whidbey Island, Washington. The testing occurred in March 2002 at which time the air and water temperatures were suitable for testing at the lower operating temperature limits of the equipment (snow covered the ground during most of the testing). Several tests were run during this period using various inert mine shapes as targets.

A human-factors study was also conducted using an expert from Coastal System Station in Panama City, Florida. Equipment handling, launching, and recovering were filmed, documented, and evaluated from a human-factors perspective to determine and correct any potential problems involving human interface with the UUV system.

The PARADIGM vehicle tracking system again proved invaluable during the testing. One of the tests was a cold water vehicle duration test that required the vehicle to operate continuously in the test range from sunrise to sunset. The command post was established several miles away from the operating area using a PARADIGM repeater to allow the operation to be safely monitored in a heated building protected from the elements.

The cold water duration test again highlighted one of the main advantages of the UUV for search operations over the human diver or marine mammal.

The UUV was unaffected by the cold water, driving snow, and surface winds during a search that would have been physically impossible for a human or marine mammal. Other than a few minutes to launch and recover the vehicle, all human operators were several miles from the vehicle while it searched a simulated mine danger area.

At the other end of the environmental spectrum, a warm water test was conducted in the fall of 2002 in waters in the Persian Gulf. The high water temperatures and salinity of the region provided an outstanding opportunity to test the small UUV operation in a region that the U.S. Navy has had extensive real world MCM experience.

VII. PHASE F - BLIND TESTS

During the cold water and warm water tests, the test directors also conducted "blind tests" to determine the UUV Platoon's ability to meet the required mine hunting performance specifications without prior knowledge of exercise mine locations, quantities, or type. The main objectives of these tests were to gather accurate data on system detection and classification capabilities, as well as false alarm and search rates. These tests simulated real world conditions that the UUV Platoon could expect to encounter during actual VSW MCM operations.

A third blind test was conducted in the amphibious assault training area off the Silver Strand in Coronado, California in March 2002. This test was conducted as more of an engineering evaluation rather than a tactical test of the UUV system. Artificial search geometries were created then repeated for several days to quantify contact localization accuracy, navigation repeatability, and the ability for operators to distinguish between legitimate targets and distracter "junk" that had been deliberately placed in the search field.

VIII. PHASE G - FLEET EXERCISES

During the UOES, the UUV Platoon took part in several major naval exercises and Fleet Battle Experiments. These were opportunities to interact with existing MCM systems, as well as expose the surface Navy to the new UUV technology and concepts.

A. Exercise Bank Shot 2002

This exercise involved deploying the UUV off a prototype high speed vessel (The Joint Venture HSV-X1) that the Navy is testing for use as a MCM command and control ship in littoral waters. The majority of the VSW MCM Detachment deployed from San Diego, California to embark on the Joint Venture in Little Creek, Virginia for participation in a MCM exercise off North Carolina in January 2002. The exercise was conducted in relatively cold water on a bottom profile unique to the UUV Platoon's experience. Contact

information gathered from the UUV was entered into the MEDAL system, and passed to other elements for reacquisition and identification.

Though the UUV operated without problems in the cold water, it was discovered that the battery charging system inside the UUV would not charge the batteries until the internal temperature of the vehicle reached a certain level. Again, the UOES process had brought to light valuable operating information during the exercise that would allow changes in the specifications of the equipment that otherwise may not have been addressed until a production unit had been delivered to the fleet.

B. RIMPAC 2002

Part of the EXERCISE Rim of the Pacific 2002 (RIMPAC '02) involved an MCM operation to clear a landing zone prior to an amphibious assault on a simulated enemy shore located at Barking Sands, Kauai, Hawaii. The entire VSW MCM Detachment deployed aboard the USS Duluth for a deployment to the islands of Oahu and Kauai in June 2002. After several weeks of workups off Pearl Harbor, the UUV Platoon participated in the combined MCM portion of the exercise with U.S., Canadian, Australian, and British clearance divers, and other MCM forces at Barking Sands.

RIMPAC '02 provided an excellent opportunity to interact with other nations' MCM forces while exposing them to the UUV operations and concepts. The lessons learned and techniques that were validated during RIMPAC '02 were invaluable for the UUV Platoon and the rest of the NSCT-1 during its first combat deployment less than a year later during Operation Iraqi Freedom.

C. Fleet Battle Experiment Juliet

Immediately after RIMPAC '02, the UUV Platoon was flown back to Southern California to participate in an Office of Naval Research technology demonstration using the latest in prototype UUV technology. The operators again deployed several UUVs from the Joint Venture HSV-X1. The vehicles operated simultaneously with control from an acoustic modem, linked through a RF (Radio Frequency) modem, back to the command center on the ship. With the equipment developers observing and gathering fleet feedback, the UUV Platoon was able to operate the vehicles and make recommendations based on their experience with the UOES vehicles.

IX. OPERATION IRAQI FREEDOM

At the start of Operation Iraqi Freedom, one of the primary coalition goals was the clearance of several ports in Southern Iraq of mines and hazardous devices to allow the delivery of humanitarian aid. NSCT-1 was tasked with assisting in this effort. The NSCT-1

operational debut included the successful introduction of UUVs into the field of modern warfare, and the validation of the concept of the User Operation Evaluation System and its seven phases.

On the morning of 24 March 2003, the first elements of the UUV Platoon landed in Umm Qasr, Iraq. Mine search and clearance operations began within hours of landing. Operations at Umm Qasr continued for eight days. NSCT-1 was given further tasking to search and clear the port facility of Az Zubayr, just south of Basra, Iraq. Operations in Az Zubayr were quickly completed in two days of missions. Fig. 2 shows the REMUS UUV starting a mission during Operation Iraqi Freedom. The safe arrival at the Umm Qasr port facility of the first relief ship (HMS SIR GALAHAD) with emergency supplies for the people of Iraq was directly attributed to the success of the UUV Platoon and other MCM forces in the region.

Much of the success of the UUV operations and of NSCT-1 during Operation Iraqi Freedom can be attributed to the UOES and the UUV development program. The thorough testing and evaluation conducted within the UOES resulted in a detailed understanding of the new UUV technology and of how best to employ the vehicles in a variety of scenarios. Phases B through E of the UOES resulted in a diverse group successfully moving from a concept of operations to actual wartime employment. Standard development of equipment and tactics within the Navy could take two to three times the 24 months that was actually used by the UUV Platoon.

Standard operating procedures developed in Phase B provided the foundation for operations conducted during Operation Iraqi Freedom. These procedures have laid the groundwork for future UUV development and operations. While the majority of test and evaluation was conducted in Southern California, the limits of the REMUS and the Platoon were tested during Phases C, D, and E by participating in exercises and operations throughout the U.S. and overseas. By varying the local operating areas and bottom types, and by traveling to other locations with significant environmental extremes, the REMUS was subjected to a wide variety of environmental conditions with differing depths, currents, turbidity, salinity, temperature, etc. Successful operation in a variety of environmental extremes infused the UUV Platoon with confidence in the ability of its equipment, as well as its tactics and standard operating procedures.

The UOES was essential to the success of the UUV Platoon in Operation Iraqi Freedom; from the beginning, it put the prototype UUV in the hands of the operators. The continuous stream of interaction between the end user and the developer fostered the flow of crucial information regarding ruggedness, operability, interoperability, and integration.



Fig. 2. REMUS UUV starting mission during Operation Iraqi Freedom.

X. CONCLUSION

The UOES is a powerful tool for the procurement of advanced technology for the United States Military. Putting the equipment in the hands of the war fighter early in the procurement cycle allows invaluable input from the ultimate customer concerning the equipments utility, suitability, and ease of use. With over 150 UUV missions and 250 vehicle operating hours logged during the UOES period the UUV Platoon was able to develop the expertise and confidence to effectively operate these highly complex machines under wartime conditions. The UOES also gives the operational military units a new capability years before the first production units arrive, as demonstrated by the use of the REMUS UUV by NSCT-1 during Operation Iraqi Freedom.

The success of a UOES project depends heavily on early coordination and written agreement between all parties involved in the process. Successfully capturing data and documenting all phases of the UOES effort provides an invaluable source for ensuring the equipment is meeting Key Performance Parameters and provides a hard justification for the continuation of a procurement effort.

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Acronyms

AoA	Analysis of Alternatives
EOD	Explosive Ordnance Disposal
FY	Fiscal Year
HSV	High Speed Vessel
MCM	Mine Countermeasures
MEDAL	Mine Warfare Environmental Decision Aid Library
MOA	Memorandum of Agreement
NSCT-1	Naval Special Clearance Team ONE
PARADIGM	Portable Acoustic/Radio Geo Referenced Monitoring
REMUS	Remote Environmental Monitoring UnitS
RF	Radio Frequency
RIMPAC	Rim of the Pacific
RWG	Requirements Working Group
S-C-M	Search, Classify, and Map
SOP	Standard Operating Procedure
UOES	User Operational Evaluation System
UUV	Unmanned Underwater Vehicle
VSW	Very Shallow Water
WHOI	Woods Hole Oceanographic Institution